Laboratory
Sprayer Calibration

A. Four major questions to answer:

1) How much water is to be applied per acre?
2) How many acres should a tank of spray solution cover?
3) How much herbicide should be added to the tank?
4) How much spray solution should be collected per nozzle to be properly calibrated?

B. Calibrating a Sprayer

Calibration is the mathematical determination of the amount of spray solution (water) applied per unit area expressed in GPA necessary to insure the appropriate rate of herbicide or other pesticide. Physically calibrating a sprayer is certainly of paramount importance but no more important than proper sprayer adjustment or calculating the appropriate rate of herbicide to be applied. Both physical calibration and calculations concerning rate of delivery, rates, etc. are involved in what we normally refer to as calibration. Proper calibration of herbicide application equipment is essential for safe, economical, and effective pest control. Sprayers should be calibrated several times during the year.

An understanding of how a sprayer operates and especially the factors influencing the amount of liquid applied is essential in getting a sprayer set up for a specific job and for properly calibrating the unit for the application rate desired. The amount of liquid that a sprayer applies to a given area can be varied by changing one or more of the following:

- Pressure that forces liquid through the spray nozzle
- Nozzle size
- Ground speed
- Spacing of nozzles on boom

Pressure should be used only to make very minor adjustments in spray volume. It takes approximately a four-fold increase in pressure to double sprayer output. Pressure changes output rate proportional to the square root of the pressure (psi).

new psi = old psi x square root (new psi/old psi)

The use of pressure to adjust output is strongly discouraged because operators tend to rely on pressure and invariably use excessively high pressure. First select the appropriate nozzle and then make very minor adjustments in pressure to obtain the needed flow rate.

Pressure should be high enough to insure proper distribution of the solution from nozzles. This can depend on nozzle type. Low-pressure nozzles are available that allow acceptable spray patterns at low pressure. If pressures in excess of 50 psi are required to give the desired delivery rate of a herbicide, then a larger nozzle should be used. Consequently, the pressure can be reduced. Remember that higher pressure increases off-target drift of the herbicide.

The proper alignment of fan nozzles is necessary for uniform coverage. Improper alignment can result in strips of (1) uncontrolled weeds and (2) crop/turfgrass injury. Nozzle spacing and height are also important. Space nozzles a distance apart (usually 20 inches) on the boom and adjust the height to give a uniform spray pattern.

The proper height for a given spacing can be calculated mathematically but 'trial and error' is simpler. Spray on concrete, asphalt, or other smooth surface and adjust the height of the boom to give a uniform overlap and distribution of the spray solution on the surface. The drying pattern is an exceptionally good 'eyeball' indicator. Improper height will result in strips where herbicide rate may be either too low or too high. Adjust height according to information provided from nozzle manufacturer, which should discuss proper overlap for different nozzles.

Nozzle tips are subject to wear over time depending on the pesticide being used, length of use, etc. Wettable powder formulations are particularly abrasive. Nozzles should be checked periodically for wear. Replace a nozzle tip if the discharge rate varies more than 10%. Do not operate a nozzle above or below the pressure listed by the manufacturer.

Ground speed is a major variable in sprayer calibration. Application rate is inversely proportional to the speed. By doubling speed, output is reduced by half.

new rate = old rate x (old mph/new mph)

Day to day maintenance and operation of sprayers is important if successful pest control with chemicals is to be achieved. Inspect sprayers daily when using and follow routine servicing and storage instructions contained in the operation and maintenance manuals supplied by the sprayer manufacturer.

C. Calibration Exercise

1) Determine the gallons per minute (GPM) you need to catch from a nozzle for your specific gallons per acre, speed, and nozzle spacing. Using the formula below, when starting the process to determine delivery rate per nozzle may be easier to catch one fourth of this in 15 seconds (1/4 of a minute). This will save you some time when calibrating, but will sacrifice accuracy somewhat.

$$GPM = \frac{(\text{Gallons Per Acre})\ (\text{Speed in mph})\ (\text{Nozzle spacing in inches})}{5940}$$

$$mL\ /\ 15\text{seconds} = \frac{(GPA)(\text{Speed in mph})\ (\text{Nozzle spacing in inches})\ (3785)}{(5940)\ (4)}$$

2) Begin by making sure all the fittings are sealed. Check the pressure gauge on the CO_2 canister. The pressure needle should not be in the red zone.
3) The spray can should be full of water (and only water). Make sure the seal on the can is airtight. Open the air release valve to release air into the can. You should not be able to hear air leaking from the can.
4) Use a screwdriver to adjust the pressure initially to 25 psi. This is the starting point.
5) Have a partner hold and operate the boom. You should have a stopwatch, holding the catch cup near the nozzle.
6) Have your partner turn on the sprayer to allow the pressure to build. Have them keep it on until you are finished catching.
7) At the same instant, start your stopwatch and move the cup under the nozzle. Do not allow any liquid to escape from the cup. If some does, or your timing was off, dump the cup *COMPLETELY* out and begin again.
8) After exactly 15 seconds, remove cup from the spray pattern and shut off the sprayer.
9) Carefully pour the contents of the cup in a graduated cylinder. Measure the amount you caught to the nearest ml.
10) You want the amount that you caught to be the same as the amount you calculated in step 1:
- If you caught a little too much, lower the pressure a few psi and try again.
- If you caught slightly under what you calculated, raise the psi slightly.
- If you caught a great deal too much, you may need to change the nozzle tips to a lower output range (orifice size).
- If your volume is a great deal too little, change the nozzle tips to a higher output (orifice size).

11) Remember that the higher the pressure, the smaller the droplet size (more drift).
12) Repeat steps 6-10 until the desired volume of water is caught.

D. Three calibration techniques:

1) Common sense method
2) Baby bottle method
3) Formula method

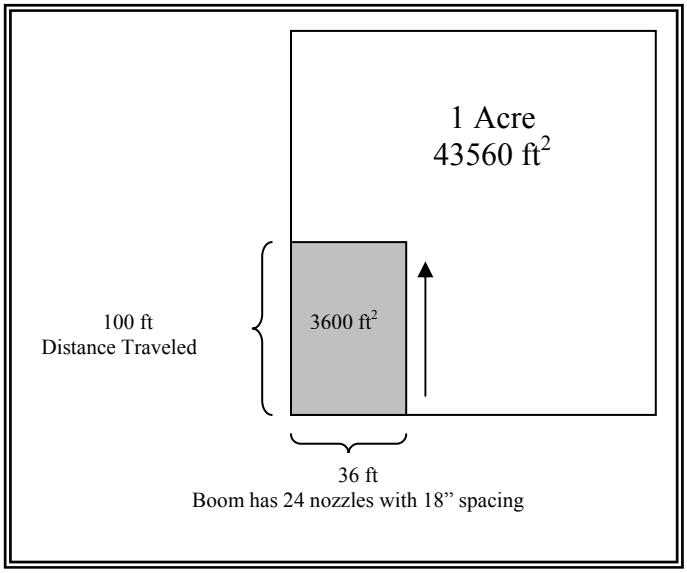

Figure 1. Common sense calibration method

Common Sense Method

36 ft x 100 ft = 3600 ft^2 (area covered)
3600 / 43560 = 0.08264 acre

1. $\frac{10\ Gal}{1\ acre}$ = X/ 0.08264 acre

2. Travel time: 22.6 sec. to travel 100 feet

3. $\frac{0.08264\ gal}{24\ nozzles} = \frac{0.0344\ gal}{nozzle}$

4. 0.0344 Gal x 3785 ml/Gal = 130 ml/nozzle

5. To be properly calibrated at 10 GPA, you must catch 130 ml/nozzle in 22.6 sec.

Speed = $\frac{100\ ft}{22.6\ sec} \times \frac{60\ sec}{1\ min} \times \frac{60\ min}{1\ hour} \times \frac{1\ mile}{5280\ ft}$ = 3.02 MPH

or

1 MPH = 88 ft/min 60 sec / 22.6 sec = 2.65(100)
Traveled 100 ft in 22.6 sec = 265 ft in 60 sec (1 min)

$\frac{265\ ft}{88\ ft}$ = 3.02 MPH

Figure 2. Speed determination

Baby Bottle Method

This method does not require you to know the speed of the tractor in MPH. The tractor used and the gear and throttle setting (RPM) should be recorded. This method is also referred as the $1/128^{th}$ of an acre method.

$\frac{43{,}560}{128}$ = 340 Distance in feet = 340/nozzle spacing in feet

1. Use the chart for the distance to drive in the field and the nozzle spacing for the boom.
2. Set the throttle for spraying and record the seconds required to drive the measured distance.
3. If you are using a broadcast boom with nozzles spaced evenly, catch the output from one nozzle for the time noted in Step 2. If the row width value is used catch spray from all nozzles per single row for the time noted in Step 2.
4. Ounces collected will equal gallons per acre.

Nozzle Spacing or Row width in inches	*Distance in feet*
40	102
38	107
36	113
34	120
32	127
30	136
28	146
26	157
24	170
22	185
20	204
18	227
16	255
14	291

Figure 3. Baby bottle calibration method

Formula Method

1. $GPM = \frac{(GPA)\ (MPH)\ (NS\text{" or Band Width"})}{5940}$
2. Catch the amount from one nozzle (or all nozzles if more than one nozzle is used for banded application)
3. Usually much easier if gallons are converted to milliliters and minutes into 15 second intervals

E. Calculation of Herbicide Rates

Solid formulations: $\frac{\text{Rate}}{\%} = \text{Amount to apply}$

If formulation is 75 WP, DF, DG, or G, then % = 75% or 0.75
Want to apply 1 lb ai/A. What are the pounds of product to be applied / acre?

$\frac{1 \text{ lb ai/A}}{0.75} = 1.33 \text{ lb of product /A}$

Liquid formulations: $\frac{\text{Rate}}{\text{lb ai/gal}} = \text{Amount to apply}$

If formulation is 4 L, EC, or F, then lb ai/gal = 4
Want to apply 1 lb ai/A. What is the lb of product to be applied /A?

$\frac{1 \text{ lb ai/A}}{4 \text{ lb ai/gal}} = 0.25$ gal prod./A or 1 quart/A (4 lb per gal so 1 lb per quart)

F. Broadcast vs. Banding

Broadcast – Application of a herbicide to the entire field
Banding – Application of a herbicide to only a portion of the field

Band applications are usually made directly over the center of the row, while the middles between the rows are left untreated.

For clarification use the terminology of traveled vs. treated acreage:

- *Broadcast application* - when sprayer travels over 1 acre of land, 1 acre has been treated (treated = traveled acres)

- *Banding application* - the sprayer may still travel over 1 acre of land, however, only a percentage of the traveled acre is treated (treated does not equal traveled acres).

Example 1. Banding a herbicide on a 20 inch band. Row spacing is 40 inches. How many treated acres will be covered when the sprayer has traveled over 1 acre?

$$\frac{\text{20" band}}{\text{40" row}} \times 1 \text{ acre} = 0.5 \text{ acres}$$

0.5 acres will have been treated

Example 2. You are spraying Asulox on a 36" band on 72" a sugarcane row. Your sprayer is calibrated to deliver 20 GPA.

1. Visualize that you are only treating half the acre that you travel over.

2. Broadcast rate of 4 quarts / treated acre, then band rate is

   (0.5 acres) =2 qts / acre (traveled).

3. If you have a 200 gallon spray tank and your sprayer is calibrated to deliver 20 GPA broadcast, how many traveled acres will you be able to cover with the band per load?

   $$\frac{\text{200 gallons water}}{\text{20 GPA}} = 10 \text{ acres broadcast per load}$$

   $$\frac{\text{10 acres traveled}}{0.5} = 20 \text{ traveled acres per load}$$

4. Important to remember that the concentration of Asulox in the water in the tank is the same regardless of whether you broadcast or band. Difference is that more acreage is traveled with the sprayer when herbicide is applied on a band.

Calibration Examples

Example 1

A local farmer has a rhizome johnsongrass problem in his cotton fields. You recommend that he use Assure II 0.88 EC to control this problem at a rate of 0.069 lb ai/A. You also recommend the addition of a crop oil concentrate at a rate of 1% volume per volume (v/v). His sprayer is equipped with a 300 gallon spray tank. He has not calibrated his sprayer, but he wants to apply the solution at 15 GPA at 3.0 MPH. His boom has 40 nozzles spaced 20 inches apart.

A. What is the GPM in mls that should be caught from each nozzle to be properly calibrated?

B. How many acres can be treated per tank load?

C. How much Assure II should the farmer add to the spray tank? (oz.)

D. How much crop oil should he add to the 300 gal. tank.

Example 2

T-Jim Griffineaux has decided to use Aatrex 4L and Sinbar 80 WP for preemergence weed control in his sugarcane. Because of cost, he plans to band his herbicides on a 30" band and cultivate the middles of his 72" rows. He plans on using Aatrex at 1.25 lb ai/A and Sinbar at 2 lb ai/A on a band. His sprayer has two 200 gallon tanks and he wants to apply the herbicide solution in 20 GPA. He hasn't had time to calibrate his sprayer, but he knows that in 100 ft it takes him 13.62 sec.

A. What is the speed of his sprayer? (MPH)

B. How many mls must he catch/nozzle in 60 sec to be calibrated correctly?

C. How much of each herbicide must he use per acre to apply the correct lb ai/A?

D. How many traveled acres can he cover with the two 200 gallon tanks? How many treated acres?

E. How many pounds of Sinbar and gallons of AAtrex must he add to each tank?

Useful Formulas

CALIBRATION FORMULAS

$$\text{gpm/nozzle} = \frac{7.5}{\text{sec/pt}}$$

$$= \frac{\text{gpa X s X w}}{5{,}940}$$

$$\text{gpa} = \frac{5{,}940 \text{ X gpm/nozzle}}{\text{s X w}}$$

$$= \frac{44{,}500}{\text{s X w X sec/pt}}$$

$$= \frac{43{,}560 \text{ X gal discharged}}{\text{swath width (ft) X length of run (ft)}}$$

$$\text{mph} = 0.682 \text{ X } \frac{\text{length of run (ft)}}{\text{time (sec)}}$$

gpa .....gallons per acre, broadcast basis
gpm .....gallons per minute
mph .....miles per hour
sec .....seconds
pt .....pints
ft .....feet
s .....ground speed (miles per hour)
w .....nozzle spacing on boom or band width (inches)

CALIBRATION FORMULAS (METRIC)

$$\text{L/min/nozzle} = \frac{60}{\text{sec/L}}$$

$$= \frac{\text{L/ha X s X w}}{600{,}000}$$

$$\text{L/ha} = \frac{600{,}000 \text{ X L/min/nozzle}}{\text{s X w}}$$

$$= \frac{10\,000 \text{ X L discharged}}{\text{swath width (m) X length of run (m)}}$$

$$\text{km/h} = 3.6 \text{ X } \frac{\text{length of run (m)}}{\text{time (sec)}}$$

L/ha .....liters per hectare, broadcast basis
L/min .....liters per minute
km/h .....Kilometers per hour
sec .....seconds
m .....meters
s .....ground speed (kilometers per hour)
w .....nozzle spacing on boom or band width (centimeters)

DETERMINING VOLUME

Volume of a cylinder is radius squared × 3.1416 × length of cylinder.

Volume of cone is radius squared × 1.0472 (e.g., round hopper bottom).

Volume of pyramid is area of base × 1/3 the height. (e.g., square hopper bottom).

VOLUME CONVERSION FACTORS:
(U.S. Customary Measures)

Cu. ft. × 7.48 equals gallons.

Cu. ft. × 62.4 equals pounds water.

Gallons × 8.330 equals pounds water.

Gallons × 0.1337 equals cu. ft.

Cu. in. ÷ 1,728 = cu. ft.

Cu. yd. × 27 = cu. ft.

Cu. ft. ÷ 27 = cu. yds.

DETERMINING AREA

To find circumference of a circle when diameter is known, multiply diameter by 3.1416 (approx. 3-1/7).

To find diameter when circumference is known, divide circumference by 3.1416 or multiply by 0.3183.

Area of circle = radius squared × 3.1416; or diameter squared × 0.7854.

Area of rectangle or square = length × width.

Area of right triangle = length × width ÷ 2.

Area of other triangles = baxe × height at right angle to base ÷ 2 (see diagram).

Conversion Tables
U.S. to Metric

U.S. System			Metric Equivalent
LENGTH			
Unit	*Abbreviation*	*Equivalents In Other Units*	
Mile	mi	5280 feet, 320 rods, 1760 yards	1.609 kilometers
Rod	rd	5.50 yards, 16.5 feet	5.029 meters
Yard	yd	3 feet, 36 inches	0.914 meters
Foot	ft. or ′	12 inches, 0.333 yards	30.480 centimeters
Inch	in or ″	0.083 feet, 0.027 yards	2.540 centimeters
AREA			
Unit	*Abbreviation*	*Equivalents In Other Units*	
Square Mile	sq mi or m^2	640 acres, 102,400 square rods	2.590 square kilometers
Acre	A	4840 square yards, 43,560 square feet	0.405 hectares, 4047 square meters
Square Rod	sq rd or rd^2	30.25 square yards, 0.006 acres	25.293 square meters
Square Yard	sq yd or yd^2	1296 square inches, 9 square feet	0.836 square meters
Square Foot	sq ft or ft^2	144 square inches, 0.111 square yards	0.093 square meters
Square Inch	sq in or in^2	0.007 square feet, 0.00077 square yards	6.451 square centimeters
VOLUME			
Unit	*Abbreviation*	*Equivalents In Other Units*	
Cubic Yard	cu yd or yd^3	27 cubic feet, 46,656 cubic inches	0.765 cubic meters
Cubic Foot	cu ft or ft^3	1728 cubic inches, 0.0370 cubic yards	0.028 cubic meters
Cubic Inch	cu in or in^3	0.00058 cubic feet, 0.000021 cubic yards	16.387 cubic centimeters
CAPACITY			
Unit	*Abbreviation*	*U.S. Liquid Measure*	
Gallon	gal	4 quarts (231 cubic inches)	3.785 liters
Quart	qt	2 pints (57.75 cubic inches)	0.946 liters
Pint	pt	4 gills (28.875 cubic inches)	0.473 liters
Gill	gi	4 fluidounces (7.218 cubic inches)	118.291 milliliters
Fluidounce	fl oz	8 fluidrams (1.804 cubic inches)	29.573 milliliters
Fluidram	fl dr	60 minims (0.225 cubic inches)	3.696 milliliters
Minim	min	1/60 fluidram (0.003759 cubic inches)	0.061610 milliliters
		U.S. Dry Measure	
Bushel	bu	4 pecks (2150.42 cubic inches)	35.238 liters
Peck	pk	8 quarts (537.605 cubic inches)	8.809 liters
Quart	qt	2 pints (67.200 cubic inches)	1.101 liters
Pint	pt	½ quart (33.600 cubic inches)	0.550 liters
MASS AND WEIGHT			
Unit	*Abbreviation*	*Equivalents In Other Units*	
Ton	tn (seldom used)		
short ton		20 short hundredweight, 2000 pounds	0.907 metric tons
long ton		20 long hundredweight, 2240 pounds	1.016 metric tons
Hundredweight	cwt		
short hundredweight		100 pounds, 0.05 short tons	45.359 kilograms
long hundredweight		112 pounds, 0.05 long tons	50.802 kilograms
Pound	lb or lb av also #	16 ounces, 7000 grains	0.453 kilograms
Ounce	oz or oz av	16 drams, 437.5 grains	28.349 grams
Dram	dr or dr av	27.343 grains, 0.0625 ounces	1.771 grams
Grain	gr	0.036 drams, 0.002285 ounces	0.0648 grams

Conversion Tables
Metric to U.S.

Metric System			U.S. Equivalent
LENGTH			
Unit	*Abbreviation*	*Number of Meters*	
Kilometer	km	1,000	0.62 mile
Hectometer	hm	100	109.36 yards
Decameter	dkm	10	32.81 feet
Meter	m	1	39.37 inches
Decimeter	dm	0.1	3.94 inches
Centimeter	cm	0.01	0.39 inch
Millimeter	mm	0.001	0.04 inch

AREA			
Unit	*Abbreviation*	*Number of Square Meters*	
Square Kilometer	sq km or km^2	1,000,000	0.3861 square mile
Hectare	ha	10,000	2.47 acres
Are	a	100	119.60 square yards
Centare	ca	1	10.76 square feet
Square Centimeter	sq cm or cm^2	0.0001	0.155 square inch

VOLUME			
Unit	*Abbreviation*	*Number of Cubic Meters*	
Stere	s	1	1.31 cubic yards
Decistere	ds	0.10	3.53 cubic feet
Cubic Centimeter	cu cm or cm^3 also cc	0.000001	0.061 cubic inch

CAPACITY					
Unit	*Abbreviation*	*Number of Liters*	*Cubic*	*Dry*	*Liquid*
Kiloliter	kl	1,000	1.31 cubic yards		
Hectoliter	hl	100	3.53 cubic feet	2.84 bushels	
Decaliter	dkl	10	0.35 cubic foot	1.14 pecks	2.64 gallons
Liter	l	1	61.02 cubic inches	0.908 quart	1.057 quarts
Deciliter	dl	0.10	6.1 cubic inches	0.18 pint	0.21 pint
Centiliter	cl	0.01	0.6 cubic inch		0.338 fluidounce
Milliliter	ml	0.001	0.06 cubic inch		0.27 fluidram

MASS AND WEIGHT			
Unit	*Abbreviation*	*Number of Grams*	
Metric Ton	MT or t	1,000,000	1.1 tons
Quintal	q	100,000	220.46 pounds
Kilogram	kg	1,000	2.2046 pounds
Hectogram	hg	100	3.527 ounces
Decagram	dkg	10	0.353 ounce
Gram	g or gm	1	0.035 ounce
Decigram	dg	0.10	1.543 grains
Centigram	cg	0.01	0.154 grain
Milligram	mg	0.001	0.015 grain